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STUDY ON CLEANLINESS OF INTERSTITIAL-FREE (IF) STEEL CONTINUOUS CASTING SLAB

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By means of metallographic observation, scanning electron microscopy and electron probe micro analysis, the quantity, particle size, distribution, morphology and composition of inclusions in the slab were discussed in detail. Which can provide a reference for the process optimization of IF steel and the production of pure steel slabs. The results show that the content of C, N and O in the IF steel continuous casting slab produced by this plant is controlled at about 20 ppm, and the content of P and S is lower and the steel is relatively pure. Most of the inclusions are below 2 μm. Most of the inclusions are pure Al_2O_3, a small part contains a small amount of microscopic MnS.

Keywords: IF steel , continuous casting, microscopy, inclusions, cleanliness

INTRODUCTION

IF Steel, i.e. ultra-low carbon Interstitial Free Steel, is a new generation of stamping steel after rimmed steel and aluminum-killed steel, which has excellent deep drawability and no chronergy [1,2]. It has been widely used in automobile, home appliance and other industries, and has achieved rapid development in the international scope in recent years [3]. The existence of inclusions will not only affect the surface quality of IF steel, but also damage the continuity of the matrix, cause stress concentration, and then affect the deep processing performance of IF steel [4,5]. Therefore, it is of great significance to master the type, size and morphology of inclusions in if steel for improving the cleanliness and product quality of IF steel.

In this paper, the type, size, morphology and distribution of the inclusions of IF steel continuous casting slab produced by a steel plant were systematically studied in order to provide references for the process optimization of IF steel and the production of pure steel slab.

THE RESEARCH METHODS

Production equipment and process

The main process of producing IF steel in the steel plant was: 255 t top-blown converter → (RH) - (OB) → straight arc slab caster. When the If steel was produced in the plant, the end point C content of converter tapping was 0,04 % - 0,05 %, the oxygen activity was 600 ppm, and the temperature was 1 670 °C. Infrared slag detection technology was used during tapping. The average slag thickness was 75 mm, and the amount of steel left in the converter was about 5 t. The RH process was divided into three stages. First, the OB method was used to forcibly remove C, and the time was 60 s. Then, the slag was inspected from the ladle to the tundish, and the amount of steel left in the ladle was 2 t - 4 t. Finally, the tundish Ar blowing technology was adopted, and the Ar was closed after the liquid level rises to the height of the open pouring liquid level. A higher degree of superheat (35 °C - 40 °C) of molten steel and a faster casting speed (1,3 m/min) were used, which can improve the surface quality of IF steel. Using the quick-change nozzle technology, the pulling speed was reduced to 1,2 m / min, and 12 furnaces were continuously poured, and the nozzle was replaced every 6 furnaces.

Sampling and preparation

In this study, 25 × 70 × 15mm hexahedron steel samples were taken at the inner arc edge, the center and the quarter of the continuous casting slab, and the outer arc quarter. The specific sampling position was shown in Figure 1, and the serial numbers of each sample were defined as A, B, C, D.

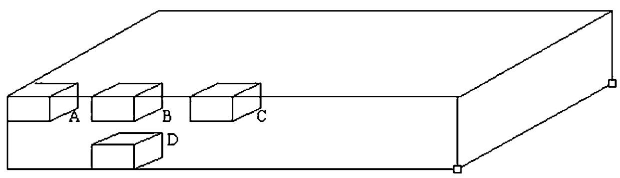

Figure 1 Sampling location

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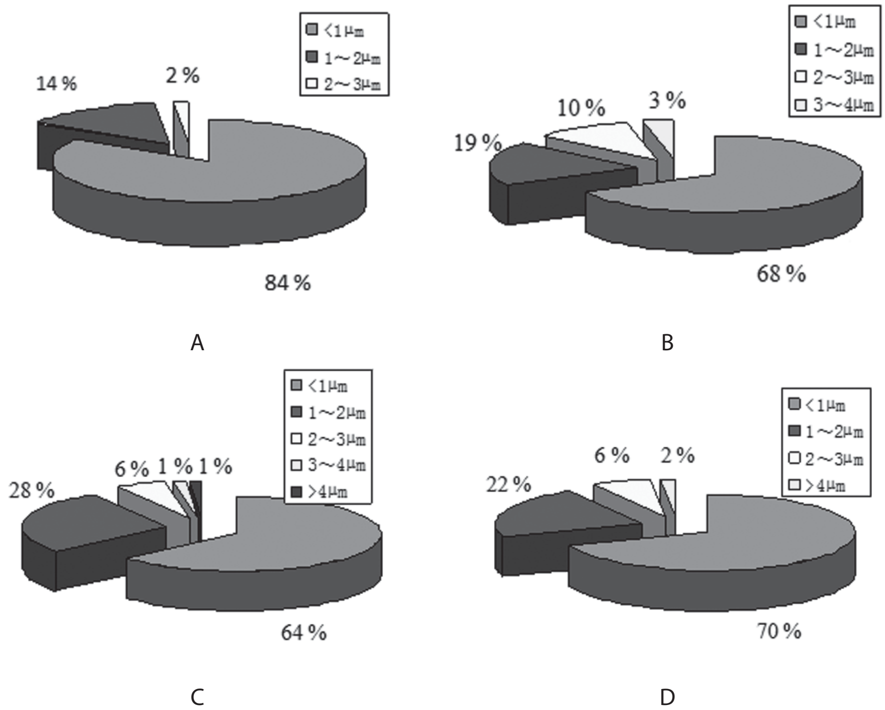

Figure 2 Numerical statement of inclusion

Experimental equipment and analytical methods

The main experimental methods were metallographic observation, scanning electron microscopy and electron probe microscopy and electron microprobe analysis. In this experiment, each prepared metallographic sample was continuously observed at 100 fields of view under a 100 × 10 multiple of an optical microscope, and the size and number of inclusions and their distribution were counted. Inclusion size was divided into five levels: < 1 μm, 1 ~ 2 μm, 2 ~ 3 μm, 3 ~ 4 μm, and > 4 μm.

RESULTS ANALYSIS AND DISCUSSIONS

Component analysis

After testing by the National Iron and Steel Materials Testing Center of the Central Iron and Steel Research Institute, the composition of the steel plant's IF steel is shown in Table 1. It can be seen from Table 1 that the steel plant's IF steel composition control has a high level. The content of carbon, oxygen, especially nitrogen is extremely low, all around 20 ppm. The phosphorus content is controlled very low, which is 60 ppm. And the sulfur content is not very low, but also controlled below 100 ppm. Niobium and titanium are added for micro alloying. With aluminum deoxidation, the total aluminum is 0,041 %. The analysis results show that the IF steel slab steel of this plant is relatively pure.

Inclusions distribution

In this study, the number and size of inclusions were counted under a metallographic microscope. And the statistical results of inclusions in each sample are shown in Figure 2. Each pie chart in Figure 2 shows the proportion of inclusions of each grade in the four samples A, B, C, and D, and the average composition of the inclusions of each grade. It can be seen that the size of most inclusions is less than 2 μm, only a small part is larger than 2 μm, and very few inclusions are larger than 3 μm. At the same time, it can be found that the number of inclusions is small and the distribution is uniform. Most of the inclusions have well-defined boundaries, most of which are triangles and quadrangles, and a few are circular.

Table 1 **Composition of IF steel / wt. %**

C	0,002	Alt	0,041
Si	0,01	Ti	0,02
Mn	0,13	Nb	0,019
P	0,006	O	0,002
S	0,009	N	0,0023
Als	0,037		

Figure 3 shows the composition of the total particle size of inclusions, and Figure 4 shows the number of inclusions of different levels per unit area in each sample.

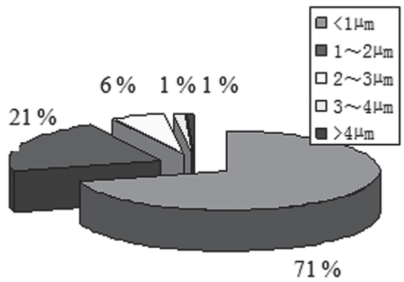

Figure 3 General distribute of inclusion size false

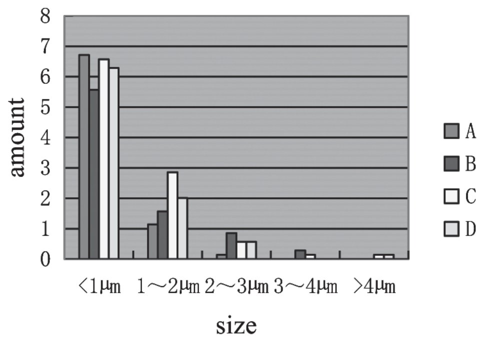

Figure 4 Number of inclusion unit area

It can be seen from Figures 3 and Figure 4 that the number of inclusions smaller than 1 μm in $1cm^2$ is less than 7, and the number of inclusions larger than 3 μm is very small. It indicates that the IF steel produced by this steel plant has few inclusions and the steel is more purer.

Morphology and composition of non-metallic inclusions

The composition of typical microinclusions and large inclusions was quantitatively analyzed by electron probe. The morphology and composition of typical inclusions obtained by experiments are shown in Figure 5 and Table 2, respectively. It can be seen from Table 2 that the composition of inclusions in the IF steel slab is mainly Al_2O_3, and most inclusions are pure Al_2O_3. A small amount of inclusions contain MnS, and a few inclusions contain a small amount of Mg elements. At the same time, some inclusions also contain Ti elements.

From the morphology of typical inclusions in Figure 5, it can be seen that inclusions have clear boundaries, and the shapes are mainly triangle, quadrilateral and polygon, which is the same as the results of metallographic study.

Table 2 **Composition of inclusion/Atom%**

	Mg	Al	S	Ti	Mn	Fe
a	1,02	33,5				44,99
b	0,25	5,39	1,05	0,49	3,36	86,08
c	0,58	31,05				47,34
d		30,88	0,47		3,36	49,54

SUMMARY

Through the above research, the following conclusions can be drawn:

The C, N, and O content of IF steel produced by the steel plant is controlled at about 20 ppm, which has a relatively high level. P content is controlled very low, S is controlled below 100 ppm, Ti and Nb elements are added for micro alloying, and the steel is relatively pure.

The number of inclusions per unit area in the slab is small and the particle size is small, most of them are below 2 μm. No inclusions larger than 5 μm are found, and the inclusions are evenly distributed. Inclusions have clear boundaries, and the shapes are mainly triangles, quadrilaterals, and polygons.

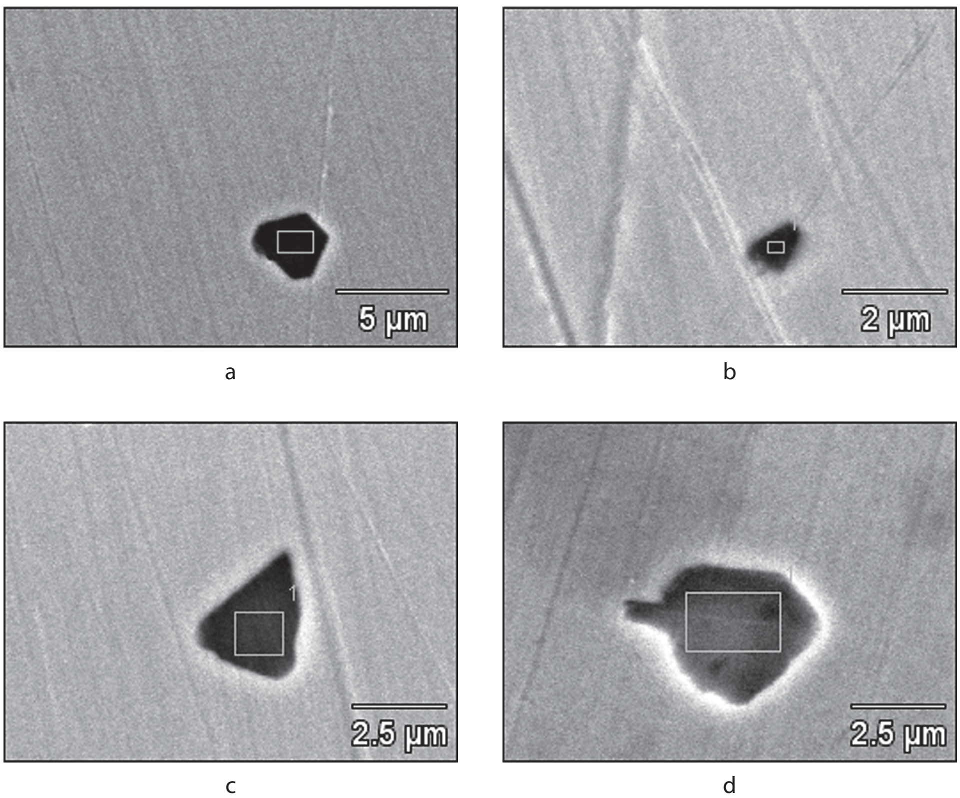

Figure 5 Typical inclusion pattern of slab

Most of the inclusions are pure Al_2O_3, a small part contains a small amount of MnS, and some inclusions contain Ti or Mg elements.

Acknowledgments

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Note: X Qinghe is responsible for English language, Liaoning, China